Update on Metacalibration for Weak Lensing Shear Measurement

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Outline

- Metacalibration
- Correlated Noise
- Correction for Correlated Noise
- Performance on Realistic Simulations

Shear Accuracy Requirements

- In order to measure the Dark Energy equation of state to the desired accuracy for DES/LSST, we must measure shear with exquisite accuracy.
- Shear calibration errors
  - DES: $\Delta\gamma/\gamma \lesssim 0.004$
  - LSST: $\Delta\gamma/\gamma \lesssim 0.001$

Metacalibration Idea from Eric Huff

- Say we have a biased shear estimator E. Then we can write

$$\begin{aligned} E &= E(\gamma = 0) + \frac{\partial E}{\partial \gamma}\gamma + ... \\ &\sim \frac{\partial E}{\partial \gamma}\gamma \equiv R\gamma \end{aligned}$$

- Use image manipulation to estimate the derivative of the estimator with respect to shear

$$R = \frac{E(+\Delta\gamma) - E(-\Delta\gamma)}{2\Delta\gamma}$$

  - Deconvolve the PSF
  - Shear the image by a small amount
  - Reconvolve by the PSF. Use a slightly larger PSF to suppress the noise amplification

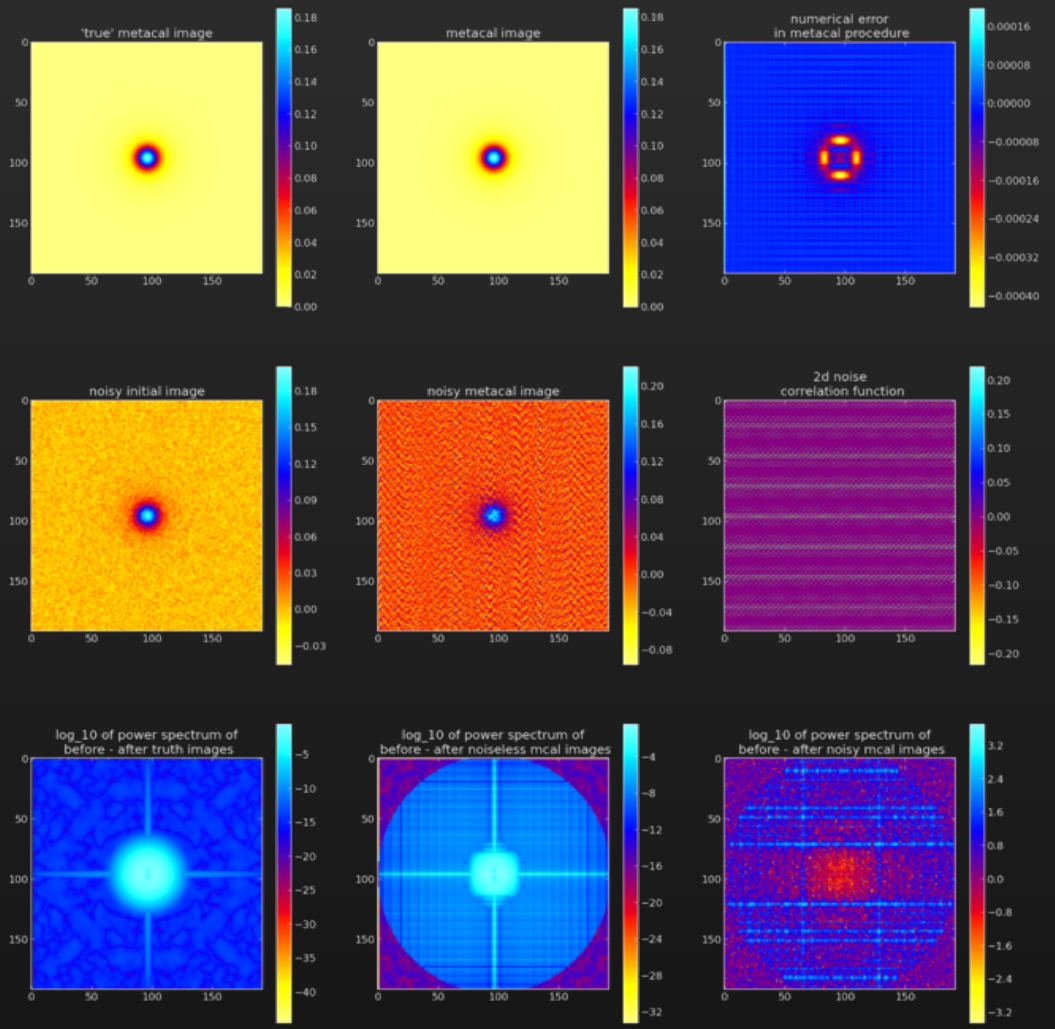
Metacalibration Idea from Eric Huff

- Corrects for modeling biases
- Corrects for *ordinary* noise-related biases
- Works well at high shear.

Correlated Noise

- These convolutions and shears result in *correlated noise*
  - After convolution, fluctuations due to noise are no longer independent between pixels
  - Shearing involves interpolation, so in a similar way fluctuations due to noise are no longer independent
- Can result in bias of order $5 - 10\%$ for very faint galaxies.

Correlated Noise Example



Correlated Noise

- Cancels from mean estimator

$$E = \frac{E(+\Delta\gamma) + E(-\Delta\gamma)}{2}$$

- Does not cancel from R

$$R = \frac{E(+\Delta\gamma) - E(-\Delta\gamma)}{2\Delta\gamma}$$

Old Correction for Correlated Noise

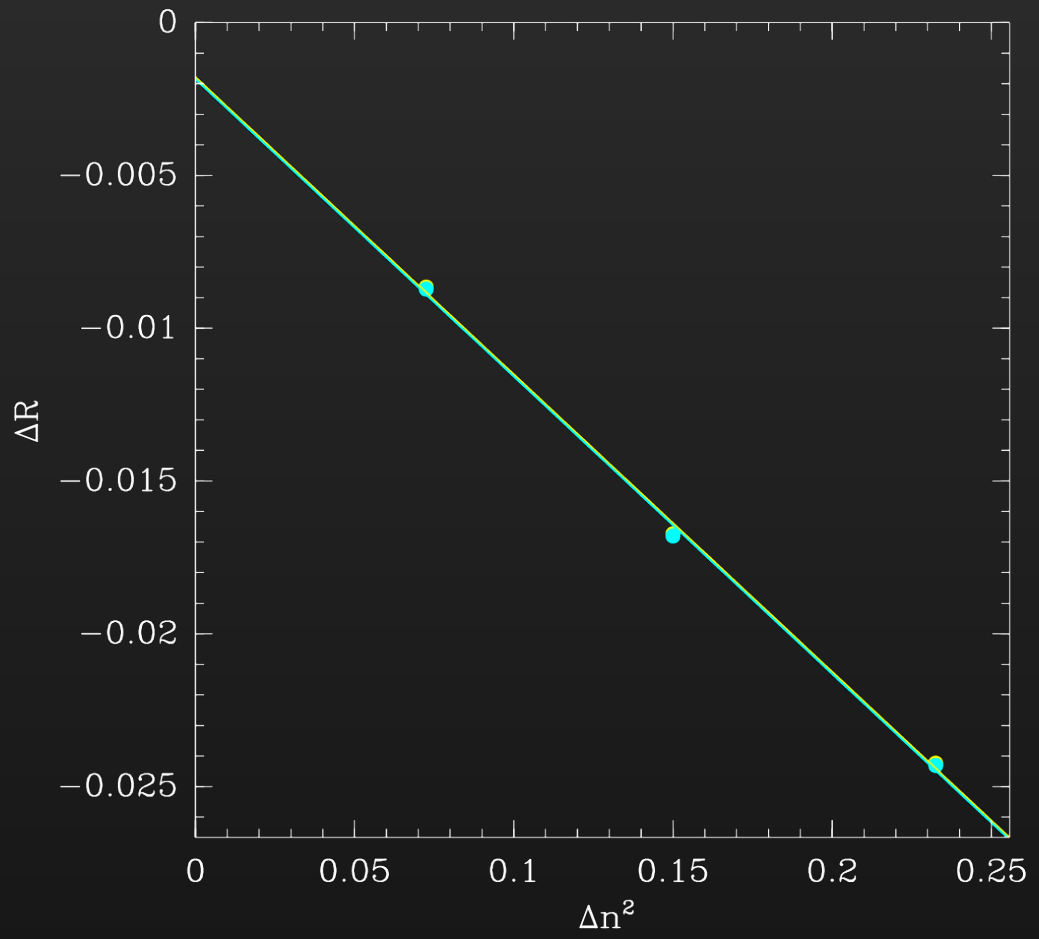
- Originally I was using deeper data to avoid the correlated noise: degrade to the noise level of the shallow data, but adding noise *after* performing metacal convolutions/shear.
- This has significant drawbacks
  - Deep data is expensive to acquire
  - Great care must be taken that the deep data is well matched to the shallow data

New Correction for Correlated Noise

- Corrections can be derived from the shallow data itself
- The best idea we have:
  - The bias due to correlated noise should scale with the correlation function of the noise. This is intuitive, but it also has been derived in general by (Hirata, private communication)
  - Bias thus scales with the noise amplitude squared
  - *Add a little noise* and look for this scaling, remove trend.

Detrending Correction for Correlated Noise

$\Delta R_{\text{noise}} = A\Delta n^2$ where ΔR is
$R(\text{noise added before}) - R(\text{noise added after})$



Note offset is not zero. Use $R_{\text{noise}} = An^2 - \text{offset}$

Performance on Simulations

- Simulations with complex galaxies:
  - bulge+disk
  - Large offsets between bulge and disk centers.
- I fit a simple gaussian, which normally results in a large "model bias", of order 10%.
- Signal-to-noise ratio distribution matched to real data, with lower bound $\gtrsim$10. Induces ordinary noise bias of order 10%

Performance on Simulations

- Model the bias as a multiplicative and an additive part

$$\gamma = (1 + m) \times \gamma_{true} + c$$

- With correlated noise corrections, the biases are reduced by at least two orders of magnitude

$$\begin{aligned} m &= (1.5 \pm 2.0) \times 10^{-3} \\ c &= (-3.4 \pm 7.0) \times 10^{-5} \end{aligned}$$

- Running now on a larger sim with real galaixes from COSMOS, DES PSF, will reach a precision of $\sim 0.7 \times 10^{-3}$

Summary

- Metacalibration is a new idea for shear recovery from Eric Huff
- Promising new correlated noise corrections that work *without the need for expensive deep data*
- On tests so far, the bias is within statistical error. More simulations are running.